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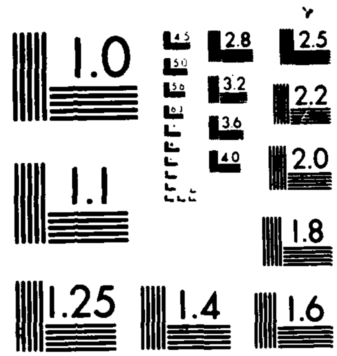

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STUDENT ESSAY

TRAINING APPLICATIONS OF ARTIFICIAL INTELLIGENCE

BY

LIEUTENANT COLONEL JOHN F. KEITH

23 MARCH 1987

US ARMY WAR COLLEGE, CARLISLE BARRACKS, PENNSYLVANIA

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Training Devices and simulations are becoming increasingly more important as a means of producing combat ready soldiers. Today's Army trainer finds himself facing training inhibitors such as complex weapons systems, rising ammunition and operating costs, safety restrictions and noise pollution. A potential solution to these inhibitors can be found in the emerging sophistication of training devices. A new field of computer technology which uses advanced programs to approximate human thought processes has particular appeal.

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This field called Artificial Intelligence (AI) has the ability to capture expertise in a particular field and use that knowledge to teach trainees or assist them in a diagnostic process. Of particular benefit to the Field Artillery is such an Expert System which can be used to teach the skills required of a Fire Support Officer (FSO). Present methods used by the U.S. Army Field Artillery School require a Fire Support Officer to develop expertise through service in the field. Expert Systems can be used to develop highly qualified FSO's so they are ready to perform when they first report to maneuver units. Additionally, Expert Systems can be developed to assist mechanics in the diagnosis and repair of the complex systems which make up todays Field Artillery. Training Developers must be made aware of this emerging technology in order to develop the next generation of training devices.

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USAWC MILITARY STUDIES PROGRAM PAPER

Training Applications of Artificial Intelligence

An Individual Essay

by

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ABSTRACT

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Training Devices and simulations are becoming increasingly more important as a means of producing combat ready soldiers. Today's Army Trainer finds himself facing training inhibitors such as complex weapons systems, rising ammunition and operating costs, safety restrictions and noise pollution. A potential solution to these inhibitors can be found in the emerging sophistication of training devices. A new field of computer technology which uses advanced programs to approximate human thought processes has particular appeal. This field called Artificial Intelligence (AI) has the ability to capture expertise in a particular field and use that knowledge to teach trainees or assist them in a diagnostic process. Of particular benefit to the Field Artillery is such an Expert System which can be used to teach the skills required of a Fire Support Officer (FSO). Present methods used by the U.S. Army Field Artillery School require a Fire Support Officer to develop expertise through service in the field. Expert Systems can be used to develop highly qualified FSO's so they are ready to perform when they first report to maneuver units. Additionally Expert Systems can be developed to assist mechanics in the diagnosis and repair of the complex systems which make up todays Field Artillery. Training Developers must be made aware of this emerging technology in order to develop the next generation of training devices.

As leaders in an Army attempting to provide for the defense of our nation in a complex, highly technological, rapidly evolving world, we find ourselves faced with the same tasks which consumed the thoughts of those who led our Army a century ago. The principal task is still to train soldiers so they possess the essential skills and confidence required to win the next war on today's incredibly hostile battlefield. Our history contains too many examples of first battles lost because of ill-trained soldiers, and the examples are not confined exclusively to the enlisted ranks. The trainers of today will not necessarily find any fewer obstacles to training, but there may be new solutions to their dilemma in the form of sophisticated, technologically advanced training devices and simulators.

The special ability of training devices becomes obvious when conventional training techniques are ineffective because of complex systems or limited training opportunities. Costly systems and systems which consume large amounts of fuel or cause excessive noise may have only one practical alternative, training devices or simulators.[1] Because of the lack of a training device for use in training repairmen for the Firefinder radar, the actual piece of equipment is used. Faults are intentionally placed in the system then the system is turned over to the student to practice fault finding procedures. Errors on the part of the students often result in damage to other subsystems which have amounted to over $100,000 a year. Certainly training to achieve nuclear surety proficiency among artillery crews would be virtually impossible without training devices. The complexity of training devices or simulators can equal or in some cases exceed the complexity of the actual weapon or system being replicated. Individual

as well as crew proficiency, even on the most complex systems, can be raised because of repetition, feedback and the resultant evaluation opportunities which are essential to all training.

Noise abatement is another benefit derived from using training devices and is becoming more important in training areas adjacent to highly populated areas such as those found in the Federal Republic of Germany or in the Northeastern United States. The impact of noise abatement is restricting the already limited artillery firing ranges at Grafenwoehr, virtually eliminating artillery firing after midnight and on weekends. The special training needs of the Reserve Components seem to be well served by training devices. Because training opportunities are so limited, maximum efficiency of training time is essential. Lack of facilities, long distance between units which must train as a team and the space constraints of an armory are problems susceptible to the training device solution. LTG H.L. Temple, Chief of the National Guard Bureau, when asked how he could improve the training in National Guard units located in highly urban areas with no training areas within easy commute replied, "much greater use of training devices."[2] As Reserve Component units are becoming increasingly vital to our war fighting capability, their special needs must be accommodated.

Often training devices have uses for which they were not intended. The Low Cost Indirect Trainer (LITR) was developed for the field artillery to curb the spiraling cost of 155 mm high explosive projectiles. The LITR round consists of a cheaper cast iron round with a black powder spotter charge instead of the milled steel projectile filled with composition B

explosive. The LITR is not the financial success some had hoped because it ended up costing almost 90% of the price of a conventional round; however, with its greatly reduced flash and bang, it has solved some of the noise reduction problem in Germany and Massachusetts. Cost reductions although desirable are not always attained, but training devices can often overcome other problems which preclude reasonable use of the actual system.

Despite all this promise, trainers are cautioned that devices and simulators are not a panacea for all training requirements that one can expect to encounter. They are for the most part created for a specific purpose and have distinct limitations.[3] They can be no better than the programs which outline their use. Devices which are so restrictively controlled at the Post level that they are next to impossible to obtain will not be used by the company commander or platoon sergeant. Training managers at all levels must integrate the use of these devices into the overall training plans of their units for the full benefit of training devices to be realized.

One of the shortcomings associated with training devices is the extremely long time that elapses between identification of the need for a device and when the device can be found in the hands of soldiers. The procedures for the acquisition of devices other than the simple training aids which can be fabricated by the local Training and Audiovisual Support Center (TASC) is the same procedure required for the acquisition of major weapon systems. The procedures calls for competitive bids to be let by interested civilian firms and often takes eight to nine years to produce a product.

Training devices can cover a rather large spectrum from simple, locally produced devices to extremely sophisticated simulators which use physical replication, symbolic or even procedural duplication to represent certain aspects of a functioning system. The level of sophistication in the Army at this point appears to lag behind the Navy and Air Force. A quick stroll around the display booths at any annual Interservice/Industry Training Systems Conference will fill the average Army trainer with awe as he views computer driven simulators that allow a pilot to land a simulated aircraft on the pitching deck of an aircraft carrier. The simulator can replicate day or night landings under any weather condition the trainer cares to dial up. All this is done without expending jet fuel or aircraft carrier time. That the Army does not have such sophisticated devices is not intended as a criticism since with the possible exception of the Stinger trainer and several helicopter simulators, the cost savings of Army training devices may not justify such levels of sophistication, nevertheless more sophistication, especially in the area of battle simulations which are used to train commanders and their staffs is not only desired, it is essential.

Training devices can generally be classified into two types, system and non-system. Those devices associated with and procured along with a piece or even a family of equipment or weapon is referred to as a system device. The need, funding and justification for these devices is usually the responsibility of the Project Manager who is managing the actual piece of equipment. All other devices are normally referred to as non-system devices. Proponent branch schools within TRADOC establish the need for any devices they require and submit to TRADOC and the Office of the Deputy

Chief of Staff for Operations and Plans (ODCSOPS), HQDA for prioritization and funding. Competition for the dollars to support these devices is extremely keen, and devices which can be used by more than one branch such as MILES usually get the money. Once funded and approved, Army Material Command's Project Manager for Training Devices (PM TRADE) located in Orlando, Florida, investigates the appropriate technologies and develops proposals for industry to consider for bidding. From a management point of view, the easiest and safest way to field a training device is along with the actual system, unfortunately when money for a project becomes tight the associated training device is the first thing to go in an effort to trim the fat. Such measures often result in false economies that manifest themselves in higher operating costs in the life cycle of the equipment. The previously mentioned example of using the Firefinder Radars to train mechanics is proof enough.

That the time for training devices and simulators has arrived is not seriously in doubt considering what I have stated previously. They are generally cheaper and sometimes present the only means of improving proficiency, but they are by no means inexpensive. Their cost must produce some measurable benefit, and the development and acquisition process must be subject to management review. This concern was manifested in a Vice Chief of Staff directed Army Management Review of training devices and simulators conducted on 15 September 1986. The review examined the training device strategy of each proponent school as well as directing an overview which was to force the proponents to articulate how their device strategies fit into the overall training strategy. Also looked at were common issues

which effected all devices. This much needed review provided guidance on the development of devices such as a directive to use embedded devices to the maximum extent possible (an embedded device is one built into the actual equipment which will allow for operator/mechanic training and eliminates the need for a stand alone trainer).

A common dilemma facing the developer of training devices today which was not addressed by the Vice Chief's review is what I call the "chicken and the egg" syndrome. The problem in particular is matching training shortfalls which can be met with training devices with what technology is available in industry. The creation of a training device starts with a training developer writing a Training Device Needs Statement (TDNS) which broadly outlines what a device must do. If that individual does not know what can be done with new technology, he cannot imagine its use to satisfy previously unsatisfied needs or needs which have been poorly met with obsolete methods and technology. By the same token, training developers should not wander from one defense contractor to another shopping for new technology against which a need can be developed.

In the remainder of this paper I will explain a new computer technology; Artificial Intelligence which shows considerable promise in training device applications. I will use the field artillery branch device inventory to analyze and cite possible uses of this technology both for new devices and as replacements for obsolete devices.

I will now attempt to examine Artificial Intelligence (AI) as best can be done by a definite layman who blanches at the sight of a personal

computer. The most difficult task facing the training developer of tomorrow is not understanding what the capabilities of AI are or what it can do for him, but understanding the plethora of definitions which are found in writings on the subject. AI is a relatively new idea which first appeared in the 1950's and in that short period of time has stirred the imaginations of those working with it as to its uses. The definition of AI is not a well-agreed upon fact, but the following is one I prefer. "AI is the part of computer science concerned with designing intelligent computer systems, that is systems that exhibit the characteristics we associate with intelligence in human behavior - understanding language, learning, reasoning, solving problems and so on."[4]

Initial work in this field was found exclusively in the universities since practical, financially rewarding uses of AI appeared to be many years away. Early attempts to duplicate human cognitive behavior were inhibited because of both hardware and software limitations, but gradually these are being overcome. The microchip and newer generation computers proved to overcome the requirement for large memories essential for AI work, and workable software emerged by the early 70's. Scientists began to specialize into the different aspects of human behavior where AI could have applications and some were more successful than others. Today we have AI computers that can understand and react to verbal commands and can "read" symbols.[5] Unfortunately, for the training developer learning was one example of cognitive behavior which was not successful. Originally it was hoped we could come to understand how humans learned. The training implications of this are obvious, shorten training time in institutions, no more

Before going on to describe what practical applications are feasible with an Expert System, let me further clarify what they are by contrasting them with ordinary applications of conventional programs. In an Expert System, the program itself is only an interpreter or reasoning mechanism and ideally the programs or reasoning rules can be changed with different but acceptable solutions being produced. In a conventional program, changes are not so easily made and may result in system crashes or worse. Perhaps the biggest differences are to be found in the input and output or answers. Expert Systems will accept any input pertinent to the domain; conventional systems will accept only specific bits of information. Conventional systems only give one correct answer or at best a limited list of acceptable answers. Expert systems on the other hand can reach several conclusions and give the probability of each occurring. It will give justifications (an explanation of how it arrived at a conclusion) and state why certain conclusions were not reached.[11] This application is one that clearly has the greatest commercial application and there are several successful programs to be found in rather diverse fields. Adequate hardware is available to handle most Expert Systems, but there does not appear to be a language that suits all kinds of systems, e.g. some may not handle graphic symbols very well although progress is continuing in this area. An Expert System by its very nature possesses an exceptionally large storage or memory and extensive search procedure which causes it to be slower than conventional programs. This shortfal may, if not overcome limit its practical use in military applications such as flight aids in high performance aircraft.

Although Expert Systems have significant limitations the one area that has proven to be economically successful is in what is referred to as the

consultation system. These systems do not replace humans, but serve as expert advisors in the solution of complex problems. Examples are those that dignose disease, interpret geophysical and sonar data, and make legal judgements. The Navy has developed an expert based simulation of the complex steam powerplants found on ships. The simulator can replicate mechanical symptoms and provide expert assistance in finding solutions. Another system called "Prospector" is used to analyze the geological finding in an area determining if mineral deposits are present in sufficient quantity to justify high cost mining. This system was responsible for the discovery of molybdenum deposits in Washington worth an estimated $100 million.[12]

As exciting as this technology may seem, it is not without some serious drawbacks which must be taken into consideration when planning for its use. The first problem is to determine the domain about which knowledge is to be gained. Next one must find the experts in that domain and capture their knowledge. Identifying experts in cardiovascular disease is not too difficult, but finding an expert in the duties of a company fire support officer (FSO) is not easy. What lieutenant can tell you all that is needed to know about being an FSO in an Armor, Infantry, Airborne, Airmobile, Light and Cavalry company, fighting in the arctic, desert, jungle or European plains. Once that expert or even better, panel of experts, have been identified they must share that knowledge with programmers (who know little about medicine or artillery fires) who weave that knowledge into an Expert System. These parties must meet regularly, say once a week, for extended periods of time depending on the size of the

domain. Once the system is created, then extensive debugging is required and only the experts can tell if answers are reasonable based on inputs given. The net result is that Expert Systems are costly, manpower intensive and require highly skilled programmers who are in short supply. Application of this costly technology by the military at present appears to be limited to decision support systems, knowledge based simulations, training aids and maintenance advisors.[13]

I have selected the Field Artillery branch for analysis to determine suitability of Expert Systems for several reasons. First, I am most familiar with how the branch functions and the training device development strategy used in developing and acquiring new devices. Secondly, the Field Artillery is a complex system of systems which combines rigid physical principles, intricate equipment and weapons and the humanistic application of these principles and equipment in the "fog of war". Additionally the ammunition and equipment is of sufficient cost to justify the development of costly Expert Systems. Furthermore any device based upon an Expert System will be confined because of cost and complexity to use only as an institutional trainer. Acquisition of initial skills rather than the continuation of skills or sustainment training would be the result. Only cost reductions associated with technological advances in storage and processing capability would allow for a small, economical device to be used in places such as the 7th Army Training Center. Use of such devices as may be developed could be made in conjunction with a battalion's rotation to Grafenweohr.

The training device strategy of the US Army Field Artillery School (USAFAS) is based upon satisfying the needs of the field as determined by feedback. Specific training shortfalls are analyzed to determine if the creation of a training device will eleviate that shortcoming. The ideal new training device must develop actual combat skills, reduce dependence on use of actual tactical equipment and costly ammunition, reduce the number of instructors, make the use of embedded technology and provide a measurable cost reduction.

The devices which are currently in the field are adequate but lack the sophistication to train some complex, highly interrelated tasks such as those performed by the fire support officer (formerly called the Fire Support Team Chief or FIST Chief) at company level and above. Artificial Intelligence is seen as the key to the creation of a simulator which can teach these tasks.[14] I agree with this assessment and will provide detailed analysis later.

To understand training devices found in the Field Artillery one must know what functions are performed by that branch. The acquisition of targets is the starting point and can be accomplished through radars, direct observation, the new Remotely Piloted Vehicle and by unmanned sensors. Once a target is identified, it is passed to the brain of the Field Artillery where command control and coordination (C^3) is performed. The output of that function is the fire order which is passed to the element which performs the final function of attacking the targets, the weapons and ammunition group. Field Artillery then is made up of a

target acquisition system, a command and control system and a weapons system. Devices can be found to train both operators and maintenance personnel who are associated with equipment or weapons in each of the systems. Each system however has inputs and outputs which cause them to interact with each other. So strong is this interaction that it is difficult to train personnel in one system without having to depend on another. The fire direction personnel (C^3 function) must have targets to attack and weapons to direct as well as feedback from both in order to develop and sustain their skills. Devices which replicate one system for use by another system are primitive if they exist at all. This area is a prime candidate for the development of new devices, but may require a level of sophistication only found in simulation. The next level where devices have an application is found in the interaction between the Field Artillery and other members of the combined arms team, Armor, Infantry, Air Defense Artillery, as well as the sister services, the Navy and Air Force. No adequate devices are found at this level. Combined arms training is only accomplished through the very costly use of actual forces in such places as the National Training Center. I don't mean to imply that actual combined arms training is not the best way to train but that it is so costly and resource intensive that it is not done often enough to sustain essential skills especially with the turnover rates which plague our units. A device which would break the habit of branches training in splendid isolation would be cheap at any cost. The level of complexity is the lowest for those devices found within a system or function. It is higher for those devices which are used between systems and highest between branches.

As I previously mentioned, Expert Systems can be used to create decision support devices, knowledge based simulators, and maintenance advisors. I can see uses for all these in various functions of the field artillery which I will explain in detail later.

One aspect of AI which some believe has particular promise is that of Intelligent Tutors. This use is a variation of the Expert System which uses an embedded test to determine the level of knowledge and ability to learn, of each student. Using this knowledge the program would design an individual learning vehicle for each student and administer that instruction.[15] I have serious doubts about the potential for this program and maintain that computer assisted instruction such as is found today will remain at its present level until much more is known about the human cognitive or learning process. Nevertheless, the US Army Air Defense School is developing a Maintenance Computer for Hawk-intelligence Institutional Instructor (MACH-III) in an attempt to overcome a major problem that has plagued the Hawk system, poorly trained maintenance personnel.[16] I do not share the optimism of the Air Defense School and will not recommend AI based computer assisted instruction because of cost, but will leave the task of teaching basic fact to conventional classroom instruction. Decision support devices, simulators and advisors are currently found in commercial application and I will limit my recommendations to these applications.

The specific skills and equipment found within the Target Acquisition function are those associated with the Firefinder radars (AN/TPQ 36 and 37), the remotely piloted vehicle (RPV) and the various human observers, the

company level fire support officer (FIST), Combat observation/Lasing Team (COLT) are the battalion observation posts (OP's). COLT's were developed as a result of the Close Support Study Group III which recommended three COLT's per maneuver brigade, each equipped with a laser designator to increase the ability of the artillery to accomodate the large number of targets found in today's ultra-hostile battlefield. OP's are created at the battalion level by using survey personnel and is an attempt to further increase target acquisition/servicing by the artillery. For purposes of this essay, I will group all observers to include the observer to be found in the recently approved advanced helicopter improved program under the same category as the company level FSO. It is the maintenance personnel in the radars and AIV who can best make use of the AI technology in the form of maintenance advisors.

In my opinion, maintenance advisors represent the best chance for successful use of AI in the Field Artillery. Although it cannot be regarded as strictly a training device, its use greatly reduces the time required to train mechanics and the requirement for subsequent sustaining training. Maintenance advisors minimize the problems associated with most Expert Systems because of the well defined domain (how many components of a piece of equipment can fail) and the identification of experts is simplified. The maintenance advisor would require no more equipment than a personal computer. It would require the mechanic to state the basic symptoms, direct that a certain test be performed and depending on the complexity of the system reach a conclusion in a half dozen iterations. For convenience sake the advisor could use speech recognition to answer

questions posed by the computer rather than go back to the terminal to type a reply. For example, the computer displays "Check the voltage at junction box 2 outlet". Is it 12 volts plus or minus 2 volts?" The mechanic who may be under a vehicle merely replies AFFIRMATIVE and the computer proceeds to the next step in the diagnostic process. The maintenance advisor could even have a built-in help system. If the mechanic did not know where junction box 2 was located, he would press a function key and a schematic or other aid would appear. The result would be fewer diagnostic problems which lead to expensive replacement of perfectly good parts not to mention greatly reduced "down time". The most persistent problem in complex systems, lack of highly skilled mechanics, would be virtually eliminated.

Maintenance advisors programs would not be limited to target acquisition systems, but have applicability in the command and control area, especially with the TACFIRE system and its replacement the Advanced Field Artillery Tactical Data Systems (AFATDS), and the weapons and ammunition group. They have special appeal in that they are relatively simple systems with a high probability of success. One must not forget that AI is a rather immature technology that may require considerable front end development and extensive debugging. I feel that starting out small and having initial successes will cause a degree of confidence in the process and make future, highly complex and more human-like application more acceptable. If cost cannot be justified at the unit/operator level, then certainly the volume at the Direct Support and General Support level will be sufficient. Development of maintenance advisors should not be confined to Field Artillery Systems, but may have commonality with all branches.

Most advocates of Expert Systems view their value in the expert assistance they lend to an individual who possesses lesser skills and certainly that is the case, however, I see additional benefits. Expert Systems when used to generate knowledge based simulations can grow an expert in far less time than normal because of the ability to subject the student to constant repetitions and instant feedback. An expert in this case is not only someone who possesses the majority of the known facts in a domain, but because of years of experience can analyze the array of facts in a situation and can automatically discount some solutions as unworkable and almost by intuition arrive at the correct conclusion. Expert Systems in the form of knowledge simulators can create experts in a fraction of the time that can be done normally. The acquisition of facts however is still confined to traditional methods. The ability to make experts strikes at the heart of one of the most vexing training problems facing Field Artillery, producing qualified fire support officers at the company and battalion level.

In the Field Artillery, the FSO is the link between the Artillery and the maneuver arms and therefore performs a highly complex task which is virtually impossible to replicate using conventional computer programming. The level of concern expressed by USAFAS is evident when one considers that two conferences are held annually at Fort Sill, one for commanders and one for fire support officers (commanders are not included). Responses from the field to USAFAS on fire support lessons learned included the following:

- The best FSO's are former commanders.
- The brigade FSO should always be a major.

- *The Battalion FSO should always be a captain.*
- The best men in the battalion regardless of rank should fill FIST and liaison slots.[17]

In a nutshell use your best, most experienced (expert) personnel in fire support positions.

A review of the knowledge required of a company level fire support officer or FIST Chief will make clear why his unique training requirements are so well suited to an Expert System solution. Keep in mind that this position calls for a lieutenant with at best one year in the Army. He should know enemy and friendly fire support capabilities and limitations (artillery mortars, tactical aircraft, and naval gunfire). He must know friendly and enemy maneuver tactics, planning style and SOP's. Additionally he must understand target engagement techniques as well as munitions effects in order to optimize effects on targets. With this knowledge he must develop fire plans that support maneuver commanders scheme. He must accomodate the maneuver commander's priorities, coordinate targets near or across boundaries to prelude fratricide, avoid target duplication, use special ammunitions such as smoke, illumination artillery deployed mines and plan for integrating FA fires and tactical air. He must be able to know how to use fires in support of the offensive, hasty attacks movement to contact, deliberate attack and then there is the defensive. Different division use different tactics when doing all of the above.[18] To say that this is a lot to expect from a young lieutenant is a mild understatement.

The best that USAFAS can do at this point is teach potential FIST chiefs all the facts or points of knowledge during the Officer Basic Course and any follow-on course and send them to units where they will get experience. History has proven that some will make the grade, but many do not. Before AI, time was the only solution to the problem. The device which would greatly improve the quality of company level FSO's would be a combination of a decision aid program, a knowledge based simulator and an interactive video device. Again a basic knowledge would be acquired by conventional means, the simulator would have the ability to generate scenarios of varying complexity which could be determined by an instructor or by an embedded test. The simulator would display information on a TV screen with another screen displaying actual views of the terrain on which the battle is to be fought. Use of the interactive video device to portray the terrain would allow the FSO to see the battlefield as he would from the vision blocks of an Infantry Fighting Vehicle. The decision aid would generate an expert solution to the fire support planning and again to the execution portion for comparison to the students solution. Since Experts Systems are not limited to a single school solution, but will produce several acceptable solutions, the learning experience becomes multiples of the solution. Students can gain experience and become far more effective than was ever possible without ever having been allowed to fail. Today's technology is capable of the device I have described above. The domain is well defined with established facts and experts are readily identifiable. If resources were unlimited, a device such as described above could be fielded within seven years. A good deal of that time would be consumed extracting the information from the experts and establishing a search mechanism for the program.

The uses of Artificial Intelligence programs which I have mentioned are those which have the most practical near term applicability. An Expert System based decision aid program would be of invaluable assistance to the fire direction officer who finds himself overwhelmed on the modern target rich battlefield. Unfortunately given today's technology, the program would take too long to reach a conclusion to be of any value. The Air Force and Army combat development community do not share my views since they are planning on using AI based decision systems in the proposed advanced fighter and experimental light helicopter (LHX). The most critical factor is that training developers must know of the advances being made in this field and its potential in revolutionizing training techniques.

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